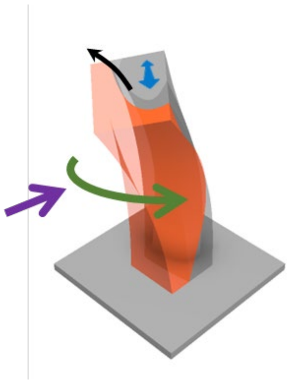
Designing for Feedback Regulation

Simplicity and Symmetry



When designing materials capable of autonomous and sophisticated responses, it seems quite obvious to build in feedback loops. Such feedback loops may couple sensor, actuator, and memory elements of the material system[1] and may provide for homeostatic behaviors or sometimes even more complex (interactive) responses.[2] Yet, designing feedback is hard: beyond what one can learn from metabolic networks and their network motifs, creating feedback-controlled systems is often a result of serendipity. In this talk, I will present a recent case study[3] on programming deformation trajectories in polymeric microactuators, where opto-chemo-mechanical feedback plays a key role. In these photo-responsive liquid crystalline elastomer microposts, the interplay of local activation, directional deformation, and feedback causes the actuators to undergo characteristic power stroke-type beating pattern, which in arrays form programmable metachronal waves. Interestingly, the feedback is also at the heart of interpillar 'communication' that enables more complex self-sorting and self-organization. Overall, the material system is surprisingly simple, which one would not *a priori* expect and ultimately raises the question about what a minimal system for self-regulation and feedback looks like.

[1] C. Kaspar, B. J. Ravoo, W. G. van der Wiel, S. V Wegner, W. H. P. Pernice, *Nature* **2021**, *594*, 345.

[2] M. M. Lerch, A. Grinthal, J. Aizenberg, *Adv. Mater.* **2020**, 1905554.

[3] S. Li, M. M. Lerch, J. T. Waters, B. Deng, R. S. Martens, Y. Yao, D. Y. Kim, K. Bertoldi, A. Grinthal, A. C. Balazs, J. Aizenberg, *Nature* **2022**, *605*, 76.

Michael M. Lerch is currently an assistant professor at the University of Groningen (the Netherlands), working on self-regulated soft materials and soft robotics (www.lerchlab.com). He holds a PhD in supramolecular and photochemistry based on his work on *'Donor–Acceptor Stenhouse Adducts'* with Prof. Feringa. During a NWO Rubicon postdoctoral fellowship in the Aizenberg group at Harvard University/WYSS Institute, he developed microstructured liquid crystalline elastomer surfaces with self-regulated motion and feedback-controlled optically active hydrogels.